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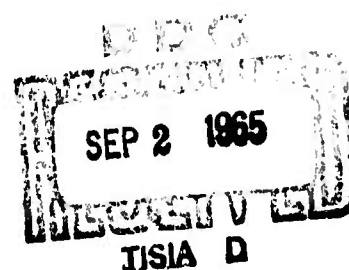
COMPLEX TARGET COVERAGE
OEG COMPUTER PROGRAM 13-63P

By R. L. Smith, G. A. Westlund,
P. E. DePoy, R. V. Ridings,
and S. A. Denenberg

Research Contribution No. 68

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Research Contribution
OPERATIONS EVALUATION GROUP
Center for Naval Analyses
THE FRANKLIN INSTITUTE
WASHINGTON 25, D. C.

26 March 1965

RESEARCH CONTRIBUTION

Operations Evaluation Group

CENTER FOR NAVAL ANALYSES

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ABSTRACT

This research contribution presents a usage manual for an IBM 7090 computer program. The program employs a Monte Carlo simulation to determine the probability of destroying individual point targets within a target complex with one or more groups of weapons. It is assumed that the groups are delivered with a bivariate normal aiming error and that the individual weapons are distributed with an independent bivariate normal ballistic dispersion. The program is designed for conditional damage data for fragmentation generated by an IBM 7090 program furnished by the U.S. Naval Ordnance Test Station (NOTS), China Lake. A flow chart, a listing of the FORTRAN program and a sample problem are included.

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I. INTRODUCTION

Previous OEG computer programs (reference (a)) determine the probability of destroying rectangular or line targets with a single group of weapons delivered with a bivariate normal aiming error, and consider the individual weapons to be distributed about their mean points of impact within the group with a bivariate normal ballistic dispersion. This program determines the probabilities of destroying stationary individual point targets at various locations within a target complex with one or more groups of weapons - making the same assumptions regarding aiming error and ballistic dispersion as were made in the previous programs.

In considering the destruction of point targets, a conditional damage function is required. The conditional damage function is defined in reference (b) as a function which gives the probability that a target which is located at a particular range and bearing from the weapon detonation point will suffer at least the stated degree of damage. Analytical functions which are often used to approximate conditional damage functions are a definite-range (cookie-cutter) function or a Gaussian function (these functions are described in detail in reference (b)). Neither of these are completely adequate however, for describing the effects of fragmentation on a point target. Therefore, this program has been designed to use the output of the IBM 7090 warhead lethality program written at the U.S. Naval Ordnance Test Station (NOTS), China Lake. The NOTS program provides, for each 5 degree sector around the weapon, the average probabilities of destroying a target located within small cells at various radii from the detonation point. It should be noted that the design of the program does not preclude the use of a cookie-cutter or Gaussian conditional damage function if the probabilities are determined for cells at the proper radii (explained in a later section of this research contribution for each 5 degree segment).

II: GENERAL DESCRIPTION

This program is a Monte Carlo simulation for use on the IBM 7090 computer. It determines the probabilities of destroying individual point targets within a target complex on the basis of the following assumptions:

a. The aiming error and the ballistic dispersion are bivariate normal, and are independent in the same coordinates, hereafter called the range and deflection coordinates (the names applied to these coordinates result from a common application of the model to bombing problems in which the range coordinate is in the direction of the flight of the aircraft and the deflection coordinate is normal to the flight path in the horizontal plane).

b. There is no cumulative damage effect, i.e., the probability of destroying the target with an individual weapon is independent of the number and locations of other weapons impacting in the vicinity of the target. For fragmentation effects this assumption is not rigorously valid since the damage criterion is often stated as some minimum number of fragments per unit area with at least a minimum energy impacting on the target. Thus, even if the number of fragments impacting on the target from any one of the weapons might be less than the number specified

by the damage criterion, the sum of the fragments from two or more weapons might exceed the minimum number.

c. The conditional damage function is symmetrical about the range coordinate through the weapon.

Limiting inputs to the program are:

- a. Number of targets, 100.
- b. Number of weapon groups, 10.
- c. Number of weapons per group, 100.
- d. Number of conditional damage function cells per 5 degree sector, 100.
(Corresponding to a maximum radius of effect of 3,920 feet).

The conditional damage data must be provided for cells at various radii from the weapon for each 5 degree sector. The cells - except for the innermost - are made approximately square in shape by selecting the outer radius of each cell to be equal to the inner radius times the factor $(1 + \sin 5^\circ)$. The outer radius of the inner cell for each sector is equal to 1 foot (see figure 1). The value of the conditional damage function is taken as 1 when the radius is less than 1 foot, i.e., for all of the inner cells. The individual cells are denoted by a pair of subscripts, $k1$, where k refers to the k^{th} sector numbering from the tail of the weapon and 1 refers to the 1^{th} cell in a given sector numbering out from the weapon. The program accepts the NOTS output, in which angles are measured relative to the bomb tail as shown in figure 1. All angles calculated in the program however, are measured from the bomb nose, positive direction counter-clockwise; but because of symmetry about the range coordinate of the bomb, values of the conditional damage function for angles that are measured from the bomb tail can be equated by a simple scheme to angles that are measured from the bomb nose; i.e., a cell having a 10 degree angle measured from the bomb nose would have the same conditional damage value as the corresponding cell in figure 1 having the 175 degree angle.

In addition to the parameters specifying the weapon effects and aiming and ballistic dispersions, the program inputs consist of parameters specifying the target locations, the angle of approach to the target for the delivery of each group of weapons (measured from the X-axis to the R-axis - see figure 2), the reliability of the individual weapons, scale factors to shrink or expand the weapon patterns, the number of dummy passes through the random number generator and the number of Monte Carlo iterations to be made.

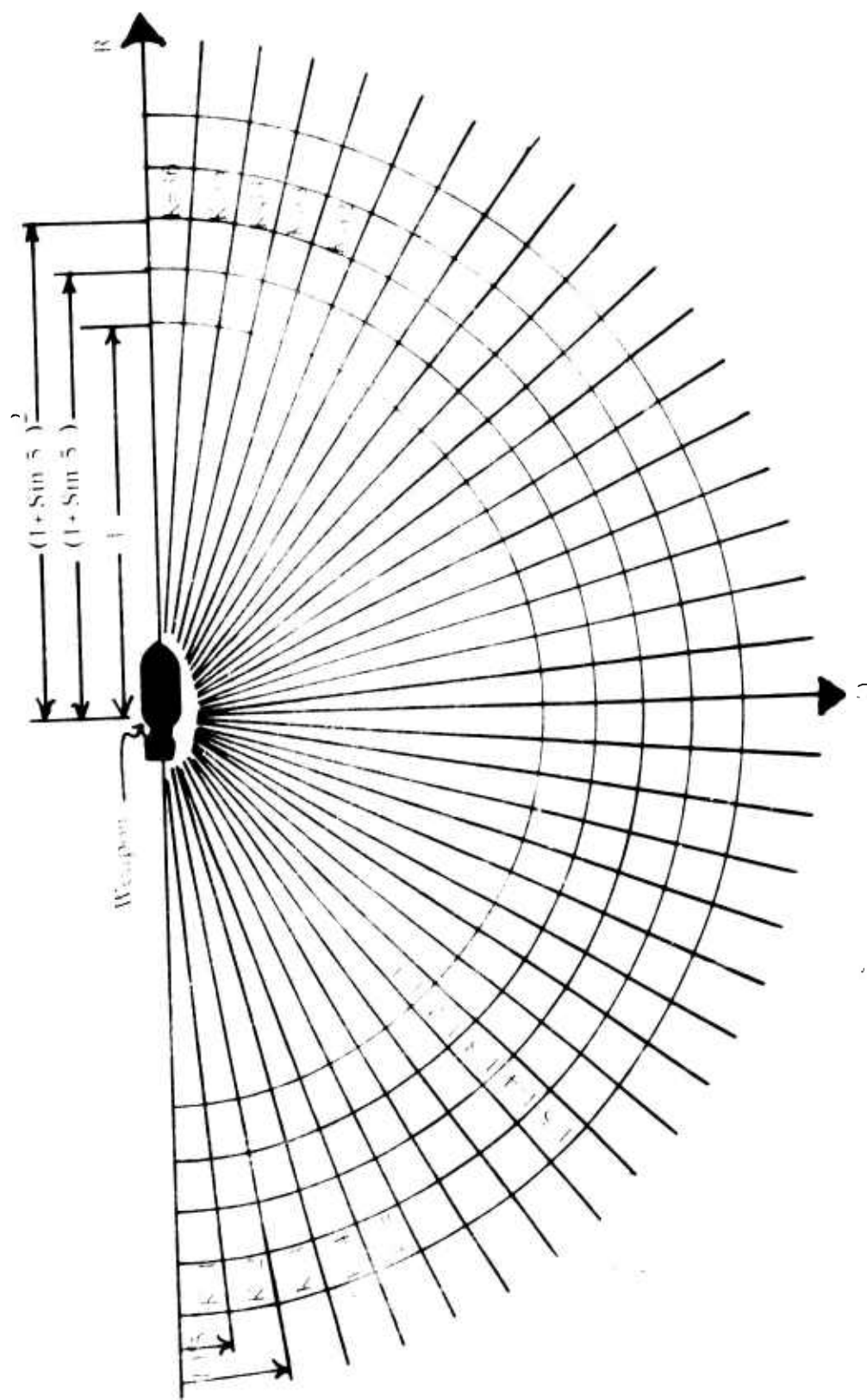


FIGURE 1

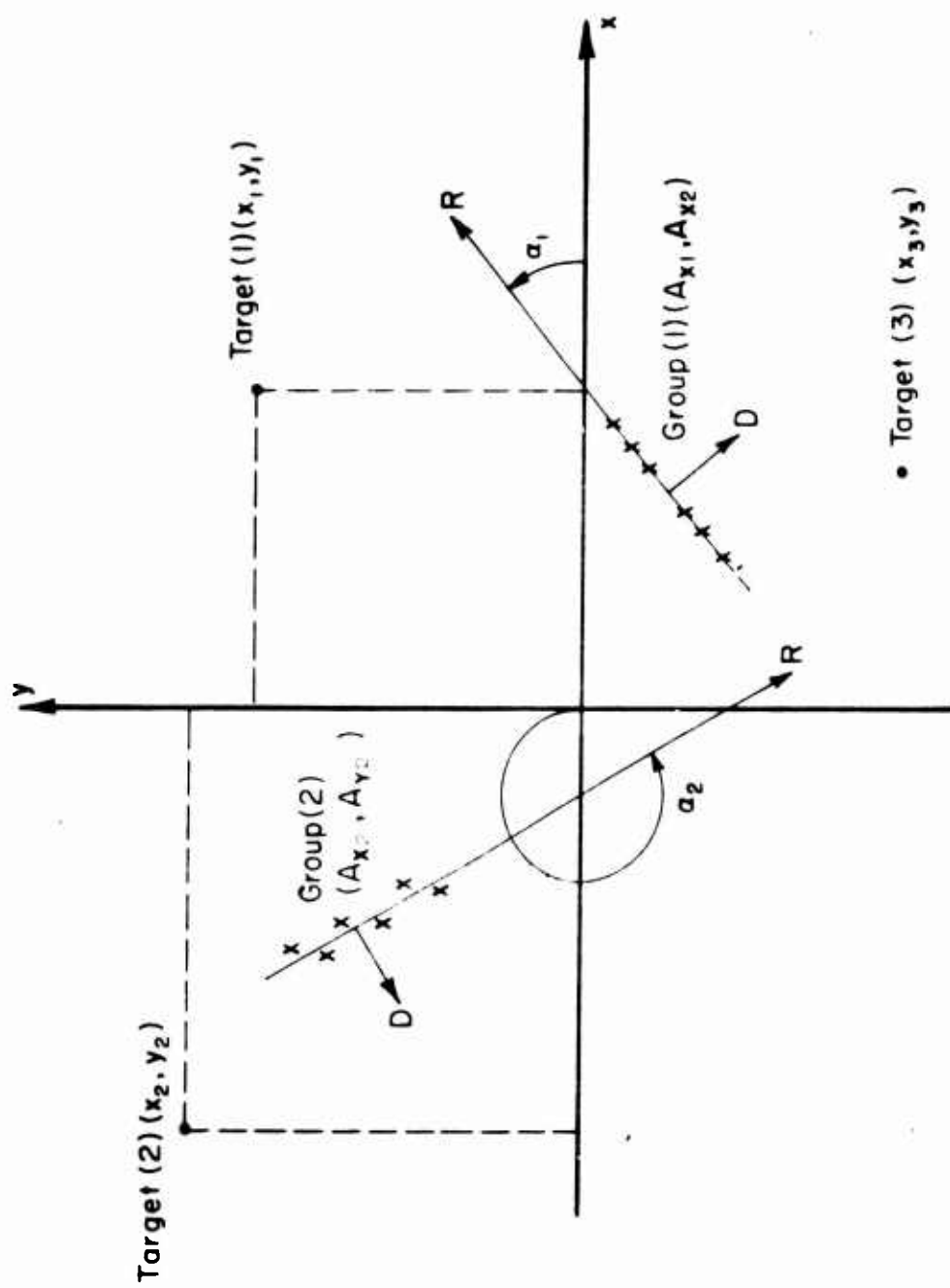


FIGURE 2

III. METHOD OF SOLUTION

The inputs for the program consist of the following parameters:

Address*	Symbol	FORTTRAN Label	Description
1, 1, 1	N_T	NT	Number of targets
1, 1, 2	N_G	NG	Number of weapon groups
1, 1, 3	I	MCI	Number of Monte Carlo iterations
1, 1, 4	n_r	NEP	Number of empty passes through random number generator
1, 1, 5	N_C	NC	Number of damage probability contours
1, 1, 6	\mathcal{R}	REL	Weapon reliability
1, 1, 7	σ_{AR}	SIGR	Range aiming error, standard deviation
1, 1, 8	σ_{AD}	SIGD	Deflection aiming error, standard deviation
1, 1, 9	σ_{BR}	BR	Range ballistic dispersion, standard deviation
1, 1, 10	σ_{BD}	BD	Deflection ballistic dispersion, standard deviation
1, 1, 11	G_R	GR	Range scale factor for weapon group
1, 1, 12	G_D	GD	Deflection scale factor for weapon group
1, 2, 1...1, 2, 10	N_i	N(I)	Number of weapons in i^{th} group
1, 3, 1...1, 3, 10	α_i	ALPHA(I)	Angle of approach for delivery of i^{th} group (degrees), $0 \leq \alpha_i < 360$
1, 4, 1...1, 4, 10	A_{Xi}	AX(I)	Aiming point of i^{th} group X-coordinate
1, 5, 1...1, 5, 10	A_{Yi}	AY(I)	Aiming point of i^{th} group Y-coordinate
1, 6, 1...1, 6, 100	X_m	X(M)	Target location of m^{th} target, X-coordinate
1, 7, 1...1, 7, 100	Y_m	Y(M)	Target location of m^{th} target, Y-coordinate
2, 1, 1...2, 1, 100	Δ_{Rij}	DELR(I, J)	Aimpoint range displacement of j^{th} weapon of i^{th} group from group aiming point
...			
...			
...			
2, 10, 1...2, 10, 100			

*The parameter addresses are explained in section IV, User's Instructions.

Address	Symbol	FORTTRAN Label	Description
3, 1, 1...3, 1, 100	Δ_{Dij}	DELD(I, J)	Aimpoint deflection displacement of j th weapon of i th group from group aiming point
...			
3, 10, 1...3, 10, 100			
4, 1, 1...4, 1, 100	C_{kl}	C(K, L)	Probability that a target located in the k th sector of the l th annulus is destroyed
...			
4, 36, 1...4, 36, 100			

Values for addresses 4, 1, 1 through 4, 36, 1 need not be entered by the user since the program itself sets these values to 1.0. The user may, however, enter whatever values he wishes for these cells and they will be used by the program.

The program flow chart and FORTRAN statements are included as appendixes A and B. The solution is obtained in the following manner:

1. Before starting the first iteration for the first data set, n_r dummy passes are made through the random number generator (see appendix C). Thus, if the same data are run more than one time, a new set of random numbers can be selected for each run.

2. For each weapon in each group, the displacement from the group reference point (Δ_R , Δ_D) is adjusted with the scale factors (G_R , G_D) to spread or shrink the pattern:

$$\Delta_{R_{ij}} = G_R \Delta_{R_{ij}} \quad (1)$$

$$\Delta_{D_{ij}} = G_D \Delta_{D_{ij}} \quad (2)$$

3. For each Monte Carlo iteration:

A. Given the group aimpoint (A_{Xi} , A_{Yi}), the standard deviations of aim error (σ_{AR} , σ_{AD}), two random numbers (n_1 , n_2) selected from a standard normal distribution (zero mean and unit variance) and the approach angle α_i , the coordinates for the pattern impact reference point relative to the X, Y axes are determined for each group:

$$R_{Xi} = A_{Xi} + n_1 \sigma_{AR} \cos \alpha_i + n_2 \sigma_{AD} \sin \alpha_i \quad (3)$$

$$\begin{aligned} \text{and for } 0 \leq R < 1, \quad l &= 1 \\ R \geq 1, \quad l &= \left\lfloor \frac{\ln R}{\ln(1 + \sin 5^\circ)} + 2 \right\rfloor \end{aligned} \quad (10)$$

(where $[x]$ is defined as the largest integer less than or equal to x).

F. From the conditional damage data for the kl^{th} cell, C_{kl} gives the probability that the m^{th} target is destroyed by the ij^{th} weapon. Given the reliability (\mathcal{R}), the probability that the m^{th} target is destroyed by at least one of the weapons is:

$$t_m = 1 - \prod_{i=1}^{N_G} \prod_{j=1}^{N_i} (1 - \mathcal{R} C_{kl}) \quad (11)$$

4. The Monte Carlo iteration is repeated (i) times and the values of t_m are accumulated for each target. At the conclusion, the estimate of the probability of destroying each target is determined by:

$$p_m = \frac{\sum_{N=1}^I t_m}{I} \quad (12)$$

IV. USER'S INSTRUCTIONS

An OEG Subroutine, 1-63S, called DATA (see appendix E) is used to read the punched card data sets into the computer. A feature of this subroutine is that data are identified and stored in the computer memory through the use of addresses that are the subscripts of the internal data array.

The addresses shown in section III are punched into cards together with the values of the parameters stored at those addresses. A data form which contains the addresses and parameter values is shown in section V for the sample problem. Any number of successive data sets may be submitted at one time as long as the data sets are separated by one blank card and the last data set in the pack is followed by two blank cards. Successive data sets may contain cards for only those parameters that have values different from the preceding data set.

V. SAMPLE PROBLEM

Four targets located at (1, 2), (3, -3), (-1, 1) and (-2, -1) are to be attacked with two groups of weapons of two each. Each weapon has a "cookie-cutter" damage function with a radius of effect of 1. The standard deviations of aim error are 3 in the range coordinate and 1 in deflection. The ballistic dispersion

$$R_{Yi} = A_{Yi} + n_1 \sigma_{AR} \sin \alpha_i + n_2 \sigma_{AD} \cos \alpha_i \quad (4)$$

$$(i = 1, 2, \dots, N_G)$$

B. For each weapon in the group, the group impact reference point (R_{Xi} , R_{Yi}), the weapon displacement from the reference point (δ_{Rij} , δ_{Dij}), the standard deviations of ballistic dispersion (σ_{BR} , σ_{BD}), two standard normal random numbers (n_3 , n_4) for each weapon, and the approach angle α_i , the coordinates of the weapon impact point relative to the X, Y axes are determined:

$$X_{ij} = R_{Xi} + (n_3 \sigma_{BR} + \delta_{Rij}) \cos \alpha_i + (n_4 \sigma_{BD} + \delta_{Dij}) \sin \alpha_i \quad (5)$$

$$Y_{ij} = R_{Yi} + (n_3 \sigma_{BR} + \delta_{Rij}) \sin \alpha_i - (n_4 \sigma_{BD} + \delta_{Dij}) \cos \alpha_i \quad (6)$$

$$(j = 1, 2, \dots, N_i)$$

C. For each target, the separation distance (squared) from each weapon is determined using the target location (X_m , Y_m) and the weapon impact points (X_{ij} , Y_{ij}):

$$R^2 = (X_{ij} - X_m)^2 + (Y_{ij} - Y_m)^2 \quad (7)$$

D. If the square of separation distance, R^2 , is less than the square of maximum radius of effect of the weapon, R_{\max}^2 , the relative bearing of the target from the weapon is determined using an OEG Subroutine, ACOSD (see appendix D).

$$\theta = \left| \cos^{-1} \left(\frac{X_m - X_{ij}}{R} \right) - \alpha_i \left(\frac{Y_m - Y_{ij}}{|Y_m - Y_{ij}|} \right) \right| \quad (8)$$

E. The conditional damage contour cell numbers, k and l , are then determined as follows:

$$\begin{aligned} \text{for } 0^\circ < \theta < 5^\circ, & \quad k = 1 \\ 5^\circ < \theta < 10^\circ, & \quad k = 2 \\ \vdots & \quad \vdots \\ 175^\circ < \theta < 180^\circ, & \quad k = 36 \end{aligned} \quad (9)$$

is 1 in range and 0.5 in deflection. The reliability of the weapons is 0.8. The centers of both groups are aimed at the origin of the x-y axis (0,0) and the weapons are spaced along the range coordinate 2 units apart. One group is delivered at an angle of 30° to the x-axis, the other at an angle of 150° to the x-axis.

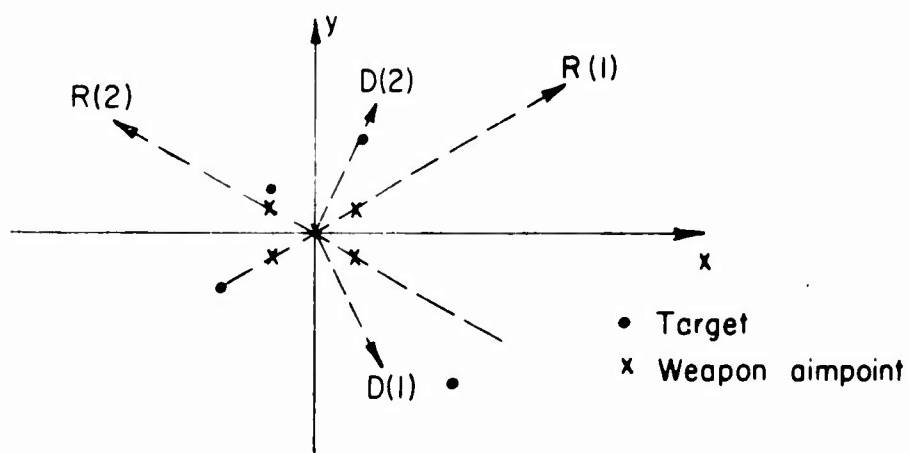


FIG. 3: SAMPLE PROBLEM

The input data are shown on the attached sample data form.

VI. KEYPUNCH INSTRUCTIONS

Keypunch instructions for the use of DATA Subroutine, 1-63S, are contained in appendix E.

VII. OPERATOR'S INSTRUCTIONS

Run under control of the Bell System on the IBM 7090. No special instructions.

VIII. TIMING

This program requires approximately:

$$\frac{1}{150} \times N_T \times I \times \sum_{i=1}^{N_G} N_i \text{ seconds}$$

where

N_T = number of targets

I = number of Monte Carlo iterations

$\sum_{i=1}^{N_G} N_i$ = number of weapons in all groups summed.

COMPLEX TARGET INPUTS

CENTERS	TARGETS	WEAPON GROUPS	ITERATIONS	RELIABILITY	RANDOM NUMBER PASSES
1	4	2	3000	0.8000	114

	RANGE	DEFLECTION
AIMING ERROR, FEET	3.0	1.0
BALLISTIC ERROR, FEET	1.0	0.5
GROUP SCALE FACTOR	1.0	1.0

GROUP NUMBER	AIMING POINTS X	Y	APPROACH ANGLE, DEGREES	NUMBER OF WEAPONS
1	0.	0.	30.0	2
2	0.	0.	150.0	2

GROUP NUMBER	WEAPON NUMBER	AIMPOINT RANGE	DISPLACEMENTS, FEET DEFLECTION
1	1	1.0	0.
1	2	-1.0	0.
2	1	1.0	0.
2	2	-1.0	0.

DESTRUCTION PROBABILITY CONTOURS

K	1
1	1.00000
2	1.00000
3	1.00000
4	1.00000
5	1.00000
6	1.00000
7	1.00000
8	1.00000
9	1.00000
10	1.00000
11	1.00000
12	1.00000
13	1.00000
14	1.00000
15	1.00000
16	1.00000
17	1.00000
18	1.00000
19	1.00000
20	1.00000
21	1.00000
22	1.00000
23	1.00000
24	1.00000
25	1.00000
26	1.00000
27	1.00000
28	1.00000
29	1.00000
30	1.00000
31	1.00000
32	1.00000
33	1.00000
34	1.00000
35	1.00000
36	1.00000

TARGET NUMBER	LOCATIONS		KILL PRCBABILITY
	X	Y	
1	1.0	2.0	0.118
2	3.0	-3.0	0.059
3	-1.0	1.0	0.239
4	-2.0	-1.0	0.184

CNA COMPUTER DATA SUBMITTAL FORM

Submitted by: J. Doe Date: 1 August 1964
 Program No. 13-63P Est. Time 4 min. Classification Unclass.

Special Instructions: _____

Address	Value	Address	Value	Address	Value	Address	Value
1,1,1	4	1,6,1	1				
1,1,2	2	1,7,1	2				
1,1,3	3000	1,6,2	3				
1,1,4	114	1,7,2	-3				
1,1,5	1	1,6,3	-1				
1,1,6	.8	1,7,3	1				
1,1,7	3	1,6,4	-2				
1,1,8	1	1,7,4	-1				
1,1,9	1	2,1,1	1				
1,1,10	.5	3,1,1	0				
1,1,11	1	2,1,2	-1				
1,1,12	1	3,1,2	0				
1,2,1	2	2,2,1	1				
1,3,1	30	3,2,1	0				
1,4,1	0	2,2,2	-1				
1,5,1	0	3,2,2	0				
1,2,2	2	—	b —				
1,3,2	150	—	b —				
1,4,2	0						
1,5,2	0						

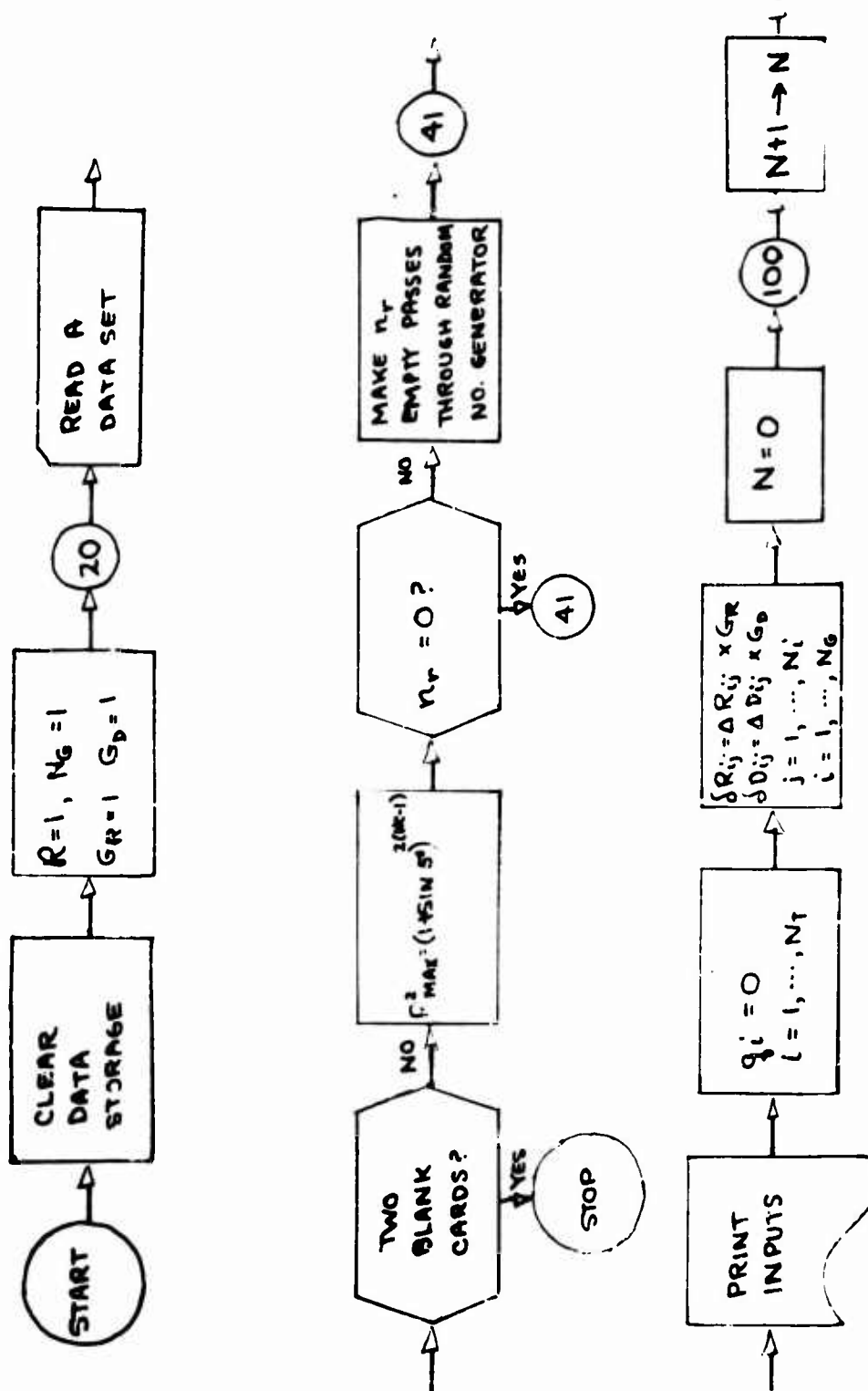
NOTES:

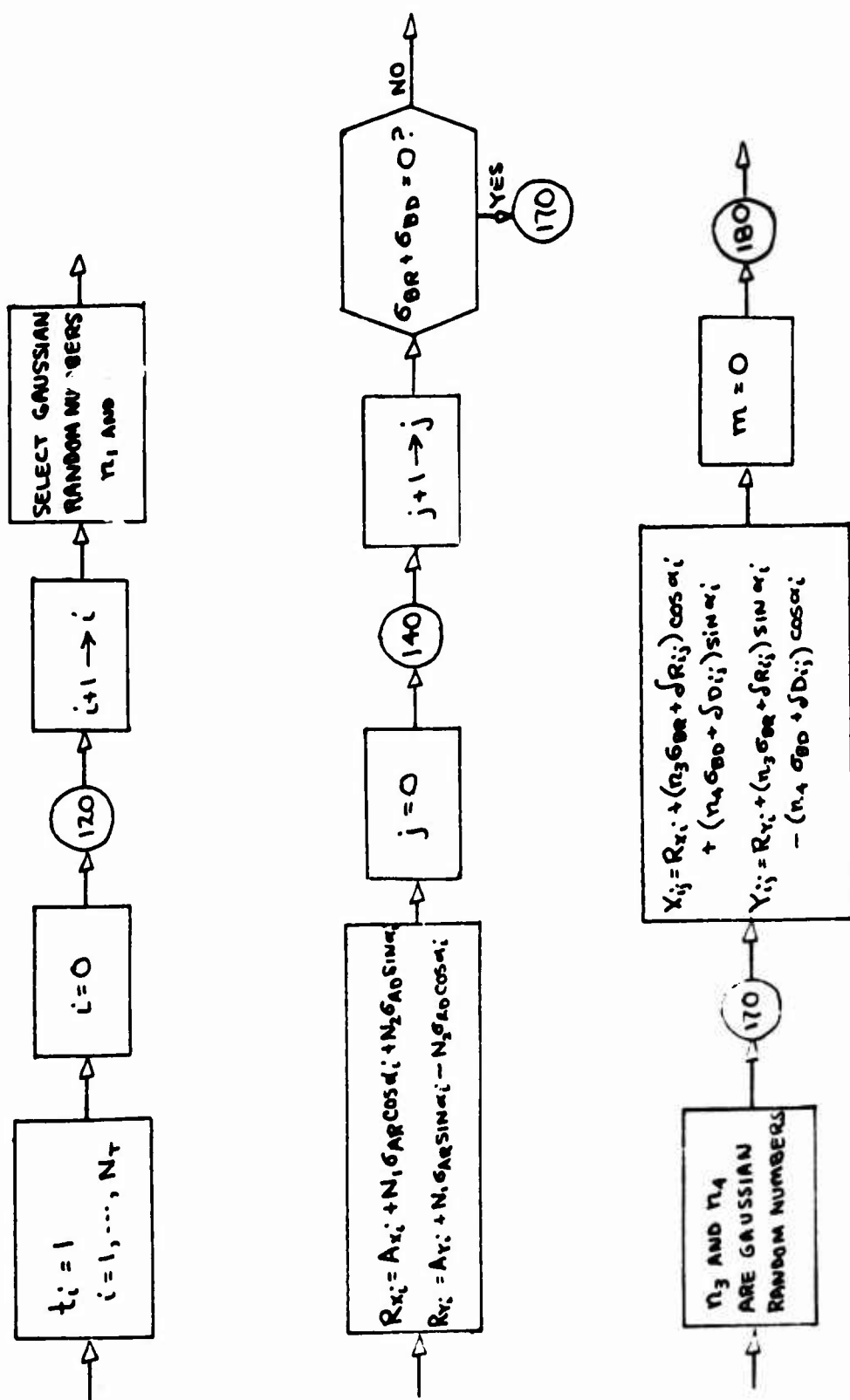
1. A value of zero must be entered as 0, not left blank.
2. Decimal pts. may be omitted if understood to follow the rightmost digit.
3. The value 3×10^{-5} may be entered as .00003 or 3-5, not as 3×10^{-5} .
4. The factor portion of a value may not contain more than 8 digits.
5. The exponent portion of a value must lie within the range ± 39 .
6. Exponents may be omitted if zero. If not, they must be signed.
7. Blank cards should be indicated by: — b —

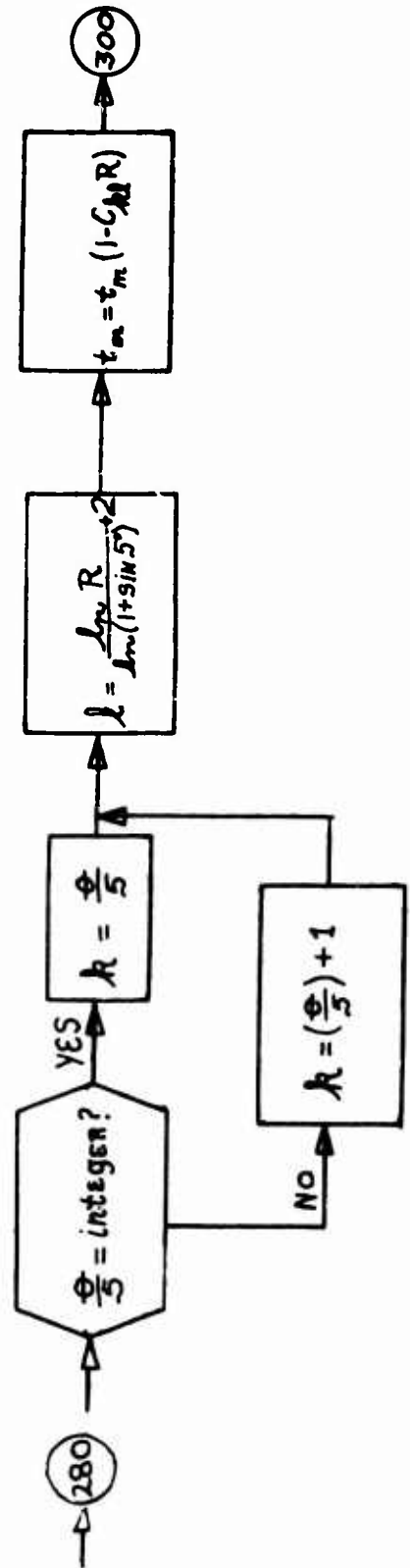
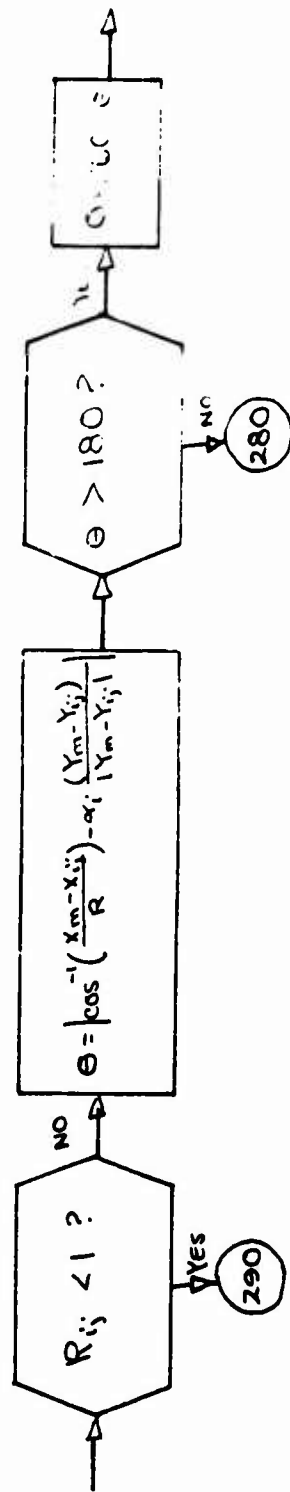
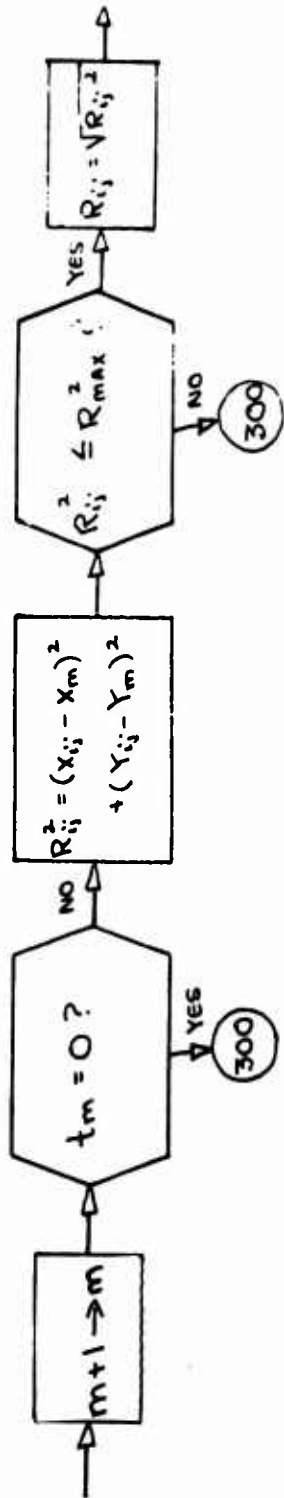
- References: (a) NAVWAG Interim Research Memorandum, NIRM-12; "Usage Manual for a Computer Program to Compute the Effectiveness of Groups of Weapons against Rectangular and Line Targets" Unclassified 11 Dec 1959
- (b) OEG Study 626, "Probability-of-Damage Problems of Frequent Occurrence" Unclassified 11 Dec 1959

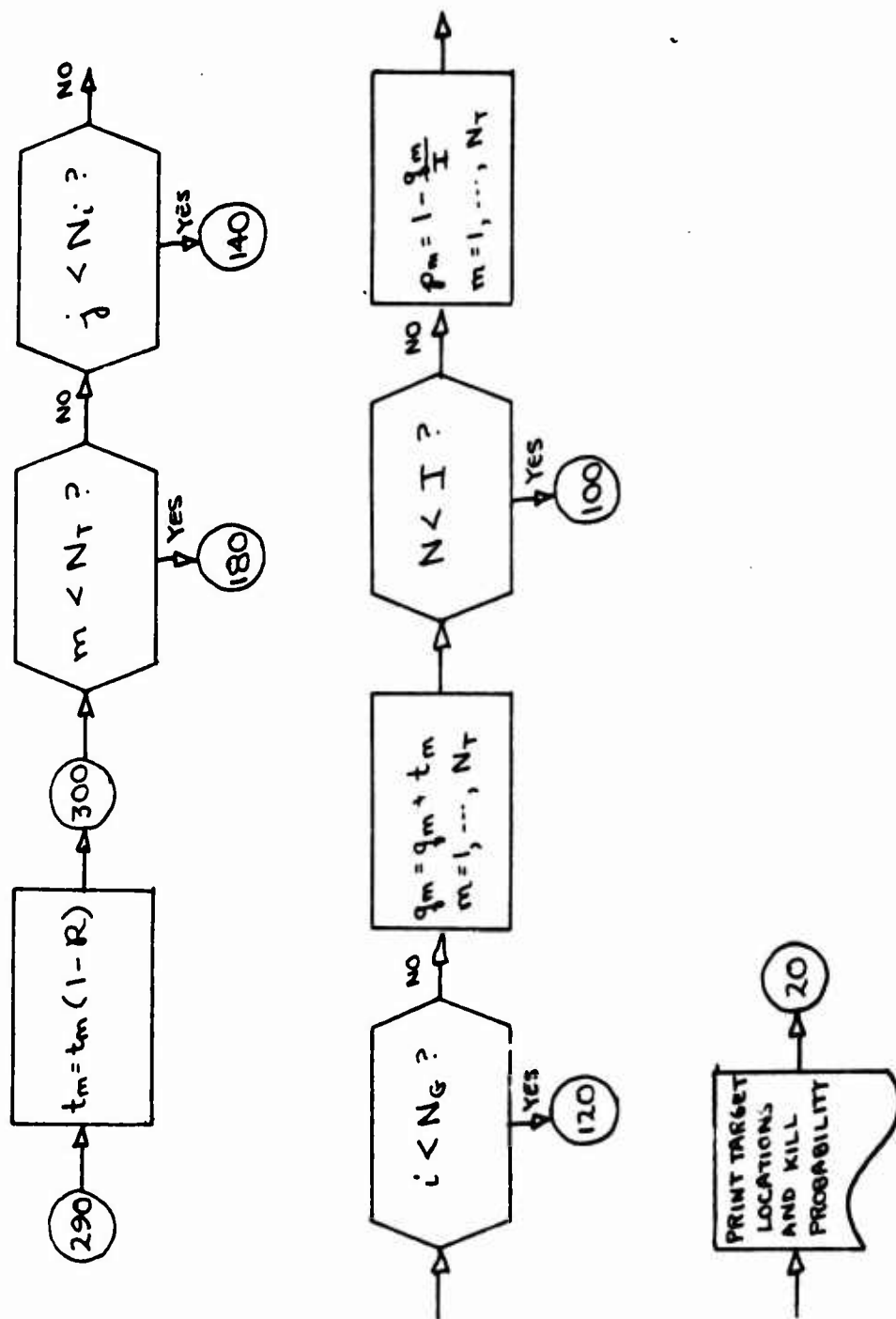
APPENDIX A
FLOW CHART

A-1
(REVERSE BLANK)









APPENDIX B
PROGRAM LISTING

B-1
(REVERSE BLANK)

```

        DIMENSION D(4,36,100), DELR(10,100), DELD(10,100), P(100), Q(100),
        IT(100), X(100), Y(100), N(10), ALPHA(10), AX(10), AY(10), COSA(10)
        2. SINA(10), RN(2),C(4,36,100),LL(10)
        EQUIVALENCE (D,C),(D(721),REL),(D(865),SIGR),(D(1009),SIGD),
        1(D(1153),BR),(D(1297),BD),(D(1441),GR),(D(1585),GD)
        DO 10 I=1,14400
10      D(I)=0.0
        DO 15 K=1,36
15      C(4,K,1)=1.0
        REL=1.0
        GR=1.0
        GD=1.0
        NG=1
20      CALL DATA (C,4,36,100,IND)
        IF (IND-1) 30,420,20
30      NT=D(1,1,1)
        NG=D(1,1,2)
        MCI=D(1,1,3)
        NEP=D(1,1,4)
        NC=D(1,1,5)
        ATERM=1.0+SINDF(5.0)
        NCX=2*(NC-1)
        RMAXSQ=ATERM**NCX
        IF (NEP) 41,41,35
35      DO 40 I=1,NEP
40      CALL GRNUMB (DUMMY)
        D(1,1,4)=0.0
41      DO 45 I=1,NG
        N(I)=D(1,2,1)
        ALPHA(I)=D(1,3,1)
        AX(I)=D(1,4,1)
        AY(I)=D(1,5,1)
        II=N(I)
        DO 45 J=1,II
        DELR(I,J)=D(2,1,J)
45      DELD(I,J)=D(3,1,J)
        PRINT 50
50      FORMAT (1H1, 38X, 41HC O M P L E X   T A R G E T   I N P U T S)
        PRINT 51
51      FORMAT (////13X, 8HCONTOURS, 5X, 7HTARGETS, 5X, 13HWEAPON GROUPS,
        1 5X, 10HITERATIONS, 5X, 11HRELIABILITY, 5X, 20HRANDOM NUMBER PASS
        2ES)
        PRINT 52, NC, NT, NG, MCI, REL, NEP
52      FORMAT (//15X, I4, 9X, I3, 12X, I2, 13X, I5, 10X, F6.4, 15X, I5)
        PRINT 53
53      FORMAT (////42X,5HRANGE,15X,10HDEFLECTION)
        PRINT 54, SIGR, SIGD
54      FORMAT (//10X, 18HAIMING ERROR, FEET,13X, F6.1, 17X, F6.1)
        PRINT 55, BR, BD
55      FORMAT (10X, 21HBALLISTIC ERROR, FEET,10X, F6.1, 17X, F6.1)
        PRINT 56, GR, GD
56      FORMAT (10X, 18HGROUP SCALE FACTOR,13X, F6.1, 17X, F6.1)
        PRINT 57
57      FORMAT (////////12X, 5HGROUP,14X, 13HAIMING POINTS,11X, 15HAPPROACH
        1ANGLE,9X, 9HNUMBER OF)
        PRINT 58
58      FORMAT (12X, 6HNUMBER, 11X, 1HX, 15X, 1HY, 13X, 7HDEGREES, 14X,
        17HWEAPONS)
        PRINT 59

```

```

59 FORMAT (1H0)
DO 60 I=1,NG
60 PRINT 61, I, AX(I), AY(I), ALPHA(I), N(I)
61 FORMAT (13X, 12, 11X, F6.1, 10X, F6.1, 12X, F5.1, 16X, 13)
PRINT 62
62 FORMAT (1H1, 12X, 5HGROUP, 7X, 6HWEAPON, 6X, 28HAIMPOINT DISPLACEMENTS, FEET)
PRINT 63
63 FORMAT (13X, 6HNUMBER, 6X, 6HNUMBER, 9X, 5HRANGE, 7X, 10HDEFLECTION)
PRINT 59
DO 64 I=1,NG
PRINT 59
II=N(I)
DO 64 J=1,II
64 PRINT 65, I, J, DELR(I,J), DELD(I,J)
65 FORMAT (14X, 12, 9X, 13, 9X, F6.1, 9X, F6.1)
NCP=NCP-1
JL=JL-1
JU=JU-1
67 IF (NCP-10) 68,68,69
68 JU=JU+NCP
NCP=0
GO TO 70
69 JU=JU+10
NCP=NCP-10
70 JL=JL+10
PRINT 71
71 FORMAT (1H1, 41X, 32HDESTRUCTION PROBABILITY CONTOURS)
LL(I)=JL
DO 72 I=2,10
72 LL(I)=LL(I-1)+1
LLL=JU-JL+1
PRINT 73, (LL(I), I=1, LLL)
73 FORMAT (1H0, 10X, 1HK, 6X, 10(13,7X))
DO 74 KK=1,36
74 PRINT 75, KK, (C(4,KK,LNC), LNC=JL, JU)
75 FORMAT (10X, 12, 6X, 10(F7.5, 3X))
IF (NCP) 76,76,67
76 NIT=0
DO 80 I=1,NT
80 Q(I)=0.0
DO 90 I=1,NG
COSA(I)=COSDF(ALPHA(I))
SINA(I)=SINDF(ALPHA(I))
JJ=N(I)
DO 90 J=1,JJ
DELR(I,J)=DELR(I,J)*GR
90 DELD(I,J)=DELD(I,J)*GD
DO 95 M=1,NT
X(M)=D(1,6,M)
95 Y(M)=D(1,7,M)
100 NIT=NIT+1
DO 110 M=1,NT
110 T(M)=1.0
IG=0
120 IG=IG+1
DO 130 I=1,2
130 CALL GRNOMB(RN(I))

```

```

      RX=AX(IG)+RN(1)*SIGR*COXA(IG)+RN(2)*SIGD*SINA(IG)
      RY=AY(IG)+RN(1)*SIGR*SINA(IG)-RN(2)*SIGD*COXA(IG)
      JW=0
140  JW=JW+1
      IF (BR+BD) 170,170,150
150  DO 160 I=1,2
160  CALL GRNUMB(RN(I))
170  XX=RX+(RN(1)*BR+DELR(IG,JW))*COXA(IG)+(RN(2)*BD+DELD(IG,JW))*
      SINA(IG)
      YY=RY+(RN(1)*BR+DELR(IG,JW))*SINA(IG)-(RN(2)*BD+DELD(IG,JW))*COXA
      I(IG)
      MT=0
180  MT=MT+1
      IF (T(MT)) 300,300,190
190  RSQ=(XX-X(MT))*2+(YY-Y(MT))*2
      IF (RSQ-RMAXSQ) 200,200,300
200  R=SQRTF(RSQ)
      IF (R-1.0) 290,210,210
210  THETA=ABSF(ACOSDF((X(MT)-XX)/R)-SIGNF(ALPHA(IG),Y(MT)-YY))
260  IF (THETA-180.0) 280,280,270
270  THETA=360.0-THETA
280  IF(MODF(THETA,5.)) 282,281,282
281  K=THETA/5.
      GO TO 283
282  K=THETA/5.+1.
283  L=LOGF(R)/LOGF(ATERM)+2.0
      K37=37-K
      T(MT)=T(MT)*(1.0-C(4,K37,L)*REL)
      GO TO 300
290  T(MT)=T(MT)*(1.0-REL)
300  IF (MT-NT) 180,310,310
310  IF (JW-N(IG)) 140,320,320
320  IF (IG-NG) 120,330,330
330  DO 340 M=1,NT
340  Q(M)=Q(M)+T(M)
      IF (NIT-MCI) 100,350,350
350  DO 360 M=1,NT
360  P(M)=1.0-Q(M)/FLOATF(MCI)
      PRINT 370
370  FORMAT (1H1, 12X, 6HTARGET, 10X, 9HLOCATIONS, 14X, 4HKILL)
      PRINT 380
380  FORMAT (13X, 6HNUMBER, 7X, 1HX, 13X, 1HY, 10X, 11HPROBABILITY)
      PRINT 59
      K=0
      DO 410 M=1,NT
      K=K+1
      PRINT 390, M, X(M), Y(M), P(M)
390  FORMAT (13X, 13, 6X, F6.1, 8X, F6.1, 7X, F7.3)
      IF (K-10) 410,400,400
400  PRINT 59
      K=0
410  CONTINUE
      GO TO 20
420  PRINT 430
430  FORMAT (1H1)
      CALL ENDJOB
      END

```

APPENDIX C

GRNUMB SUBROUTINE

1. Purpose:

GRNUMB provides a floating point pseudo-random number X . The distribution of successive values of X are Gaussian with a mean of zero and a standard deviation of one.

2. Method:

Consider the set of uniformly distributed pseudo-random numbers Y_i . GRNUMB generates a sequence of Y_i by the method of congruences:

$$Y_i = 2^{-35} (5^{15} 2^{35} Y_{i-1}, \text{ mod } 2^{35})$$

over the range $0 \leq Y_i < 1$. The variance of this uniform set is

$$\sigma_Y^2 = \int_0^1 (Y - 1/2)^2 dY = 1/12.$$

If X is the mean of any selection of m of the uniform numbers Y , the Central Limit Theorem states that the variable X approaches a normal distribution where m is sufficiently large. A satisfactory value for m is 30. Values of X are generated as a sequence of X_n , where n denotes the n^{th} entry to GRNUMB.

$$X_n = \sqrt{1/m\sigma_Y^2} \sum_{i=1}^m (Y_i^{-1/2}) = \sqrt{.4} \sum_{i=1}^{30} (Y_i^{-1/2})$$

where $Y_0 = X_{n-1}$, and $X_0 = 2^{-35}$. The variance of this normal set is 1.

3. Usage:

X is obtained by use of the statement:

CALL GRNUMB (X)

in a FORTRAN program for the IBM 7090.

4. Coding Information:

See the symbolic listing on the following page. GRNUMB is written in the 7090 FAP language. It requires 40 words storage space and 900 microseconds operating time.

SYMBOLIC LISTING

FAP
REM GRNUMB G. WESTLUND 18 JUNE 1962 (7090)
REM GAUSSIAN DISTRIBUTED RANDOM NUMBER GENERATOR.
REM ENTER VIA FORTRAN STATEMENT CALL GRNUMB(X)
REM SEQUENCE STARTS AT DEC 1, YIELDS X WITH STAND. DEV. =1.
ENTRY GRNUMB
GRNUMB SXA XX1, 1
CLA 1, 4
STA F
AXT 30, 1
STZ NUM
C LDQ NUMB
MPY MULT
STQ NUMB
CLA NUMB
SUB CHAR
ARS 4
ADD NUM
STO NUM
TIX C, 1, 1
LDQ NUM
MPY MAGIC
LRS 27
TZE D
LRS 8
CLA H125
ADD H8
LLS 8
ALS 19
TRA E
D CLA H125
ALS 27
E STO NUM
CLA H125
LLS 27
FAD NUM
F STO **
XX1 AXT **, 1
TRA 2, 4
NUM HTR **
NUMB DEC 1
MULT DEC 30517578125
CHAR TIX 0, 0, 0
MAGIC DEC 0.31622780B0
H8 DEC 8
H125 DEC 125
END

APPENDIX D

ASIN SUBROUTINE

1. Purpose:

Given the floating point argument X, ASIN provides a floating point number Y, where

$$Y = \sin^{-1} X$$

or

$$Y = \cos^{-1} X$$

$$-1 \leq X \leq 1$$

$$-1 \leq X \leq 1$$

$$-\pi/2 \leq Y \leq \pi/2$$

$$0 \leq Y \leq \pi$$

Depending upon the entry to the subroutine, Y may be found in radians or degrees.

2. Method:

A series approximation (Hastings), is used to find the Arc cosine. If the Arc sine is desired, the arc cosine is subtracted from $\pi/2$. The result is then converted from radians to degrees if desired.

$$\text{Arcsin } X = \frac{\pi}{2} - \sqrt{1-X^2} \psi(X)$$

$$\psi(X) = a_0 + a_1 X + a_2 X^2 + \dots + a_7 X^7$$

$$a_0 = 1.5707, 9630, 50$$

$$a_4 = .0308, 9188, 10$$

$$a_1 = .2145, 9880, 16$$

$$a_5 = -.0170, 8812, 56$$

$$a_2 = .0389, 7898, 74$$

$$a_6 = .0066, 7009, 01$$

$$a_3 = -.0501, 7430, 46$$

$$a_7 = -.0012, 6249, 11$$

$$\text{degrees} = 57.2957, 7951, 3 \text{ radians}$$

3. Usage:

Y is obtained by use of one of the four expressions below in a FORTRAN program for the IBM 7090.

ASINF(X)

Arc sine X (radians)

ACOSF(X)

Arc cosine X (radians)

ASINDF(X)

Arc sine X (degrees)

ACOSDF(X)

Arc cosine X (degrees)

4. Coding Information:

See the symbolic listing on page D-2. ASIN is written in the 7090 FAP language. It requires 51 words storage space and 850 microseconds operating time.

SYMBOLIC LISTING

```

FAP
REM 3-62S ASIN  G. WESTLUND  7090
REM ARCSINE-ARCCOSINE SUBROUTINE.  ENTRY VIA FORTRAN
REM EXPRESSION ASIN(X) OR ACOS(X) YIELDS RADIAN.
REM ASIND(X) OR ACOSD(X) YIELDS DEGREES.
REM ARCSINE RANGE = -90 to +90, ARCCOSINE RANGE = 0 TO 180.
ENTRY ASIN, ACOS, ASIND, ACOSD
ASIND  SXD S, 4
ACOSD  SXA S, 4
      TRA *+2
ASIN   SXD S, 4
ACOS   SXA X4, 4
      STO SIGN
      SSP
      TZE D
      STO X
      CLA ONE
      FSB X
      TZE e
A      CALL SQRT
      STO R
      AXT 7, 4
      LDQ T+7-
B      FMP X
      FAD T+7, 4
      XCA
      TIX B, 4, 1
      FMP R
C      FAD PI2
      LDQ SIGN
      LLS 0
D      LXD S, 4
      TXH E, 4, 0
      CHS
      FAD PI2
E      LXA S, 4
      TXL X4, 4, 0
      XCA
      FMP CONV
X4     AXT **, 4
      STZ S
      TRA 1, 4
S      HTR O
X      HTR **

```

SYMBOLIC LISTING (Cont'd)

SIGN HTR **
ONE DEC 1.
PI2 DEC 1.5707963
R HTR **
T DEC -.0066700901, .0170881256, -.0308918810, .0501743046
DEC -.0889789874, .2145988016, -1.570796305, .0012624911
CONV DEC 57.295779513
END

APPENDIX E

DATA SUBROUTINE

1. Introduction:

Many computer programs require the flexibility of varying any or all of the parameters in a computer run. Although FORTRAN is fairly flexible in its arithmetic and control statements, its input-output statements are quite rigid. In order to read cards for instance, considerable effort must be expended by the FORTRAN programmer in writing his input statements. This subroutine eliminates some of that tedium. The concept of a "data set" is used. A data set consists of a sequence of punched cards terminated by one blank card. A parameter deck for a computer run may consist of several data sets. Such a parameter deck is terminated by two blank cards.

2. Parameter Addresses:

The primary advantage of this subroutine over FORTRAN input statements results from the use of "parameter addresses." An address is a relative location in the computer memory. It is the subscript of an array or **matrix**. For example, in an array called *X*, the parameter value X_{53} would be located at address 53. By using the parameter addresses, a user of the program need submit only those parameter values in a data set that are different from those in the previous set.

Three types of addresses are permitted by this subroutine.

- (1) A numeric address consisting of one to five characters, each of which is a digit 0 - 9. Such an address (*n*) refers to the *n*th element in a specified array.
- (2) An alpha address consisting of one to six characters, the first of which must be alphabetic (A-Z). The remaining may be alphabetic or numeric (A-Z or 0-9). Such an address refers to the *n*th element in a specified array ($1 \leq n \leq 26$), where the first character of the address corresponds to *n* as the 26 letters of the alphabet correspond to the integers 1-26.
- (3) A matrix address consisting of two or more numeric fields separated by commas. For example, the address 53, 47 refers to the element in the 53rd row and the 47th column of a two-dimensional matrix. There is no limit to the number of dimensions in a matrix address.

3. Input Card Format:

A standard submittal form (see attachment) has been designed for the analyst. This form provides for entering parameter values with their associated addresses. The user indicates blank cards to separate data sets. The keypunch operator has the option of punching one address and value per card, or, if the addresses are sequential, of punching one address and several values on a card.

Only columns 1-72 of a card are used. Each column must contain one of the following: a digit (0-9), a "+" or "-" sign or a dash, a letter (A-Z), a period, a comma, or a blank. Each punched card must contain one parameter address. The address may start in column 1, or, if desired, may start in a later column, provided all columns before it are blank. The address is terminated by at least one blank column. Only one address is permitted on the card. Succeeding columns contain one or more parameter values, each separated by one or more blank columns. A value may be signed or unsigned. The length of the value field is variable. No blanks are permitted within a value field. A value may be punched with or without an exponent. An exponent is recognized by the presence of a plus or minus sign (or dash) between the fractional part and exponent part of the value. Decimal points (periods) may be punched in either the fractional or exponent parts of a value. If more than one value is punched on a card, those after the first will be entered at sequential addresses relative to the address of the first value.

4. Usage:

A data set is read by the use of the statement:

CALL DATA (X, I)

in a FORTRAN program for the IBM 7090. The argument X is the name of an array in the program. The argument I is an indicator set by the subroutine. This indicator may be tested by the main program upon return from the subroutine. It will have a value of 0 or 1 or 2.

- 0: The subroutine has read a data set. The main program will normally proceed to operate on this data.
- 1: The subroutine has read the second blank card which terminates the parameter deck. The main program will normally terminate at this point.
- 2: The subroutine has read a "bad" data card. The main program may terminate the run, or ignore the card and return to the subroutine to read the rest of the data set.

If the cards to be read contain matrix addresses, additional arguments must be included in the FORTRAN calling statement:

CALL DATA (X, D₁, D₂, D₃, ..., D_n, I)

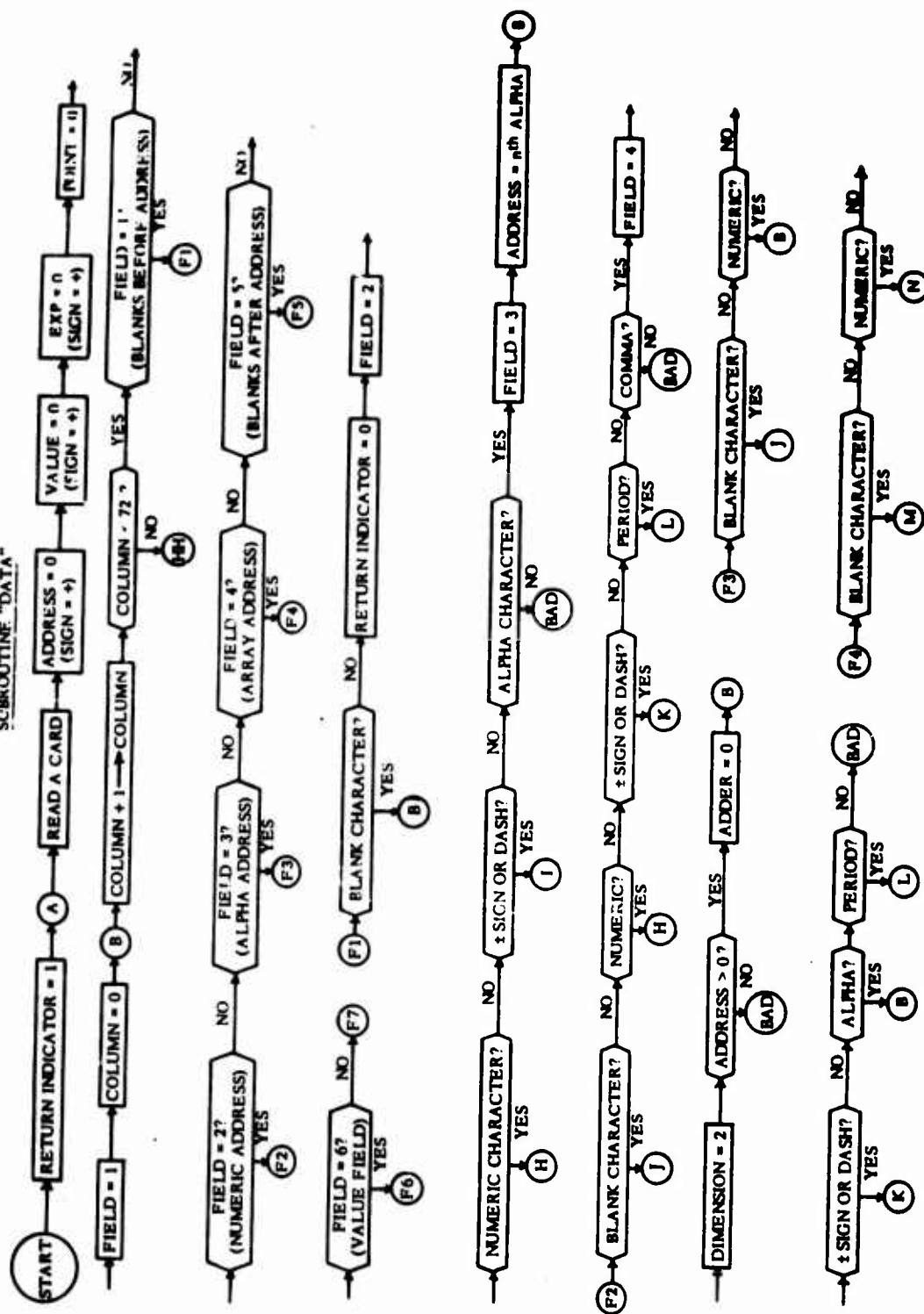
where D_i is the ith dimension of the matrix X.

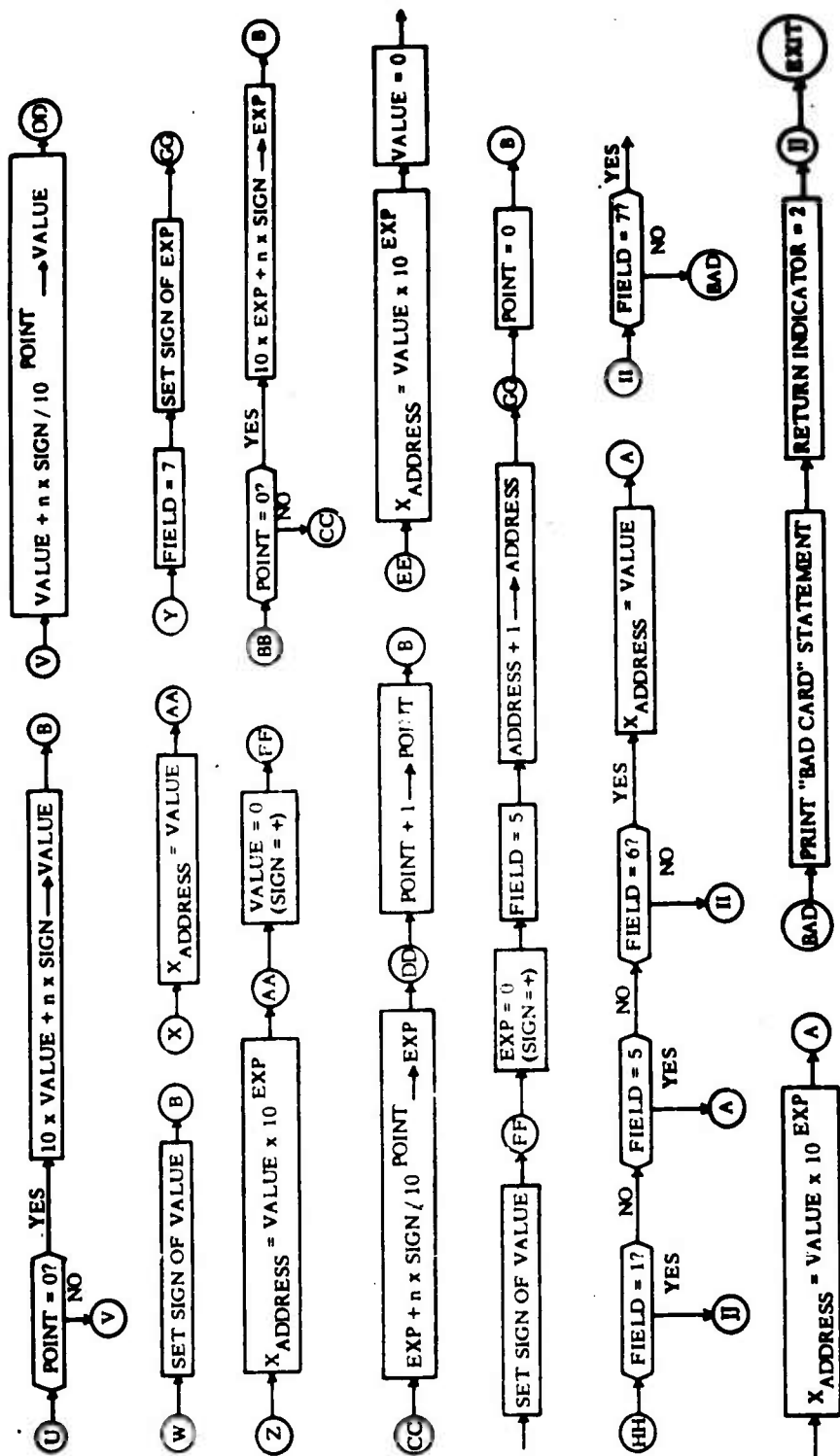
5. Method:

See the attached flow chart. DATA reads parameter values and loading addresses from cards. If sense switch 5 is up, it will read the values and addresses from tape (unit A2). It converts the values to floating point numbers, and stores them as elements of an array specified in the calling statement. The elements are specified by the addresses. If a card (or tape record) is read which contains non-permitted characters (see input card format above), DATA prints the statement "bad data card," followed by an image of the card itself.

6. Coding Information:

See the symbolic listing included in this appendix. DATA is written in the 7090 FAP language. It must be used in conjunction with the BELL system. It requires 401 words storage space.





SYMBOLIC LISTING

	FAP	
	ENTRY DATA	
DATA	SXA X1,1	
	SXA X2,2	
	SXA X4,4	
	CAL 1,4	
	ADD CORE	
	STO XLOC	
	AXT 1,1	
	SXA *+1,1	
	CAL **,4	
	ANA MASK	
	TNZ *+2	
	TXI *-4,1,1	
	SXA EXIT,1	
	TXI *+1,1,-1	
	SXA *+1,1	
	CLA **,4	
	STA A1	
	STA F1A	
	STA 112	
	AXT 1,1	RETURN INDICATOR = 1
A1	SXD **,1	
A	TSX MHREAD,4	READ A CARD
	PZE CARD	
	TRA EXIT	
	TRA BAD	
	STZ ADDRESS	ADDRESS = 0
	STZ VALUE	VALUE = 0
	STZ EXP	EXP = 0
	STZ POINT	POINT = 0
	AXT 1,1	FIELD = 1
	SXA FIELD,1	
	AXT 13,1	
A2	TNX MH,1,1	COLUMN GT 72
	AXT 42,2	
	SXA COLUMN,2	
B	LXA COLUMN,2	COLUMN = COLUMN+1
	TNX A2,2,6	
	SXA COLUMN,2	
	LDQ CARD+12,1	
	RQL 36,2	
	PXD 0,0	
	LGL 6	
	STO CHARAC	
	ORA FLOAT	
	FAD FLOAT	
	STO NUMB	
	AXT 42,4	
	CLA CHARAC	
	CAS TABLE+42,4	
	TRA *+2	
	TRA *+3	
	TIX *-3,4,1	

	TRA BAD	
	LXA FIELD,2	
	TRA F1,1,2	
	TRA F7	FIELD=7 (EXPONENT FIELD)
	TRA F6	FIELD=6 (VALUE FIELD)
	TRA F5	FIELD=5 (BLANKS AFTER ADDRESS)
	TRA F4	FIELD=4 (ARRAY ADDRESS)
	TRA F3	FIELD=3 (ALPHA ADDRESS)
	TRA F2	FIELD=2 (NUMERIC ADDRESS)
F1	TXH B,4,41	FIELD=1 (BLANKS BEFORE ADDRESS)
F1A	STZ **	RETURN INDICATOR = 0
	AXT 2,2	FIELD = 2
	SXA FIELD,2	
	TXH H,4,31	NUMERIC CHARACTER
	TXH I,4,28	SIGN OR DASH
	TXL BAD,4,2	
	AXT 3,2	ALPHA CHARACTER, FIELD = 3
	SXA FIELD,2	
	TXI *+1,4,-2	ADDRESS = NTH ALPHA
	SXA ADDRES,4	
	TRA B	
F2	TXH J,4,41	BLANK CHARACTER
	TXH H,4,31	NUMERIC CHARACTER
	TXH K,4,28	SIGN OR DASH
	TXH BAD,4,2	
	TXH L,4,1	PERIOD
	AXT 4,2	COMMA, FIELD = 4
	SXA FIELD,2	
	AXT 2,2	
	SXA DIMENS,2	DIMENSION = 2
	CLA ADDRES	TEST ADDRESS
	TZE BAD	
	TMI BAD	
F2A	STZ ADDER	ADDER=0
	TRA B	
F3	TXH J,4,41	BLANK CHARACTER
	TXH B,4,31	NUMERIC CHARACTER
	TXH K,4,28	SIGN OR DASH
	TXH B,4,2	ALPHA CHARACTER
	TXH L,4,1	PERIOD
	TRA BAD	
F4	TXH M,4,41	BLANK CHARACTER
	TXH N,4,31	NUMERIC CHARACTER
	TXH P,4,28	SIGN OR DASH
	TXH BAD,4,2	
	TXH Q,4,1	PERIOD
	TRA T	COMMA
F5	TXH B,4,41	BLANK CHARACTER
	AXT 6,2	FIELD = 6
	SXA FIELD,2	
	TXH U,4,31	NUMERIC CHARACTER
	TXH W,4,28	SIGN OR DASH
	TXH BAD,4,2	
	TXH G,4,1	PERIOD

F6	TRA BAD TXH X,4,41 TXH U,4,31 TXH Y,4,28 TXH BAD,4,2 TXH G,4,1 TRA BAD	BLANK CHARACTER NUMERIC CHARACTER SIGN OR DASH PERIOD
F7	TXH Z,4,41 TXH BB,4,31 TXH EE,4,28 TXH BAD,4,2 TXL BAD,4,1	BLANK CHARACTER NUMERIC CHARACTER SIGN OR DASH
G	AXT 1,2 SXA POINT,2 TRA B	PERIOD, POINT = 1
H	LDQ ADDRES MPY H10 XCA ACL CHARAC STO ADDRES TRA B	ADDRESS = 10 X ADDRESS + N
I	TXH B,4,30 CLA ADDRES SSM STO ADDRES TRA B	+ SIGN SET SIGN OF ADDRESS
J	AXT 5,2 SXA FIELD,2 TRA B	FIELD = 5
K	TXH L1,4,30 CLA VALUE SSM STO VALUE TRA L1	+ SIGN SET SIGN OF VALUE
L	AXT 1,2 SXA POINT,2	POINT = 1
L1	AXT 6,2 SXA FIELD,2 TRA B	FIELD = 6
M	AXT 5,2 SXA FIELD,2 TRA S	FIELD = 5
N	LDQ ADDER MPY H10 STQ ADDER TSX T1,4 MPY CHARAC XCA ADD ADDER STO ADDER TRA B	ADDER = 10 X ADDER + N X PROD
P	TXH R,4,30 CLA VALUE SSM	+ SIGN SET SIGN OF VALUE

	STO VALUE	
	TRA R	
Q	AXT 1,2	POINT = 1
	SXA POINT,2	
R	AXT 6,2	FIELD = 6
	SXA FIELD,2	
S	LXA EXIT,2	CHECK DIMENSION
	TXI *+1,2,-3	
	PXA 0,2	
	SUB DIMENS	
	TNZ BAD	
T	TSX T1,4	ADDER=ADDER-PROD
	CLA ADDER	
	SUB PROD	
	STO ADDER	
	TZE BAD	CHECK ADDER
	THI BAD	
	ADD ADDRES	
	STO ADDRES	
	CLA DIMENS	
	ADD H1	
	STO DIMENS	
	TRA F2A	
T1	SXA T4,4	PROD = PRODUCT OF DIMENSIONS
	CLA H1	
	STO PROD	
	STA T3	
	LXA DIMENS,2	
	TXI *+1,2,-1	
	LXA X4,4	
T2	CAL T3	
	ADD H1	
	STA T3	
T3	CLA **,4	
	STA *+1	
	LDQ **	
	RQL 18	
	MPY PROD	
	STQ PROD	
	TIX T2,2,1	
T4	AXT **,4	
	TRA 1,4	
U	CLA POINT	TEST POINT
	TNZ V	
	LDQ VALUE	VALUE = 10 X VALUE + N
	FMP DEC10	
	SSP	
	FAD NUMB	
	LDQ VALUE	
	LLS 0	
	STO VALUE	
	TRA B	
V	LXA POINT,4	VALUE = VALUE + N/(10**POINT)
	CLA NUMB	

	FDP DEC10	
	XCA	
	TX -2,4,1	
	LDQ VALUE	
	LLS 0	
	FAD VALUE	
	STO VALUE	
	TRA DD	
W	TXH H,4,30	+ SIGN
	CLA VALUE	SET SIGN OF VALUE
	SSM	
	STO VALUE	
	TRA H	
X	CLA XLOC	X(ADDRESS) = VALUE
	SUB ADDRESS	
	STA H+2	
	CLA VALUE	
	STO H	
	TRA AA	
Y	AXI 7,2	FIELD = 2
	SXA FIELD,2	+ SIGN
	TXH G,4,30	SET SIGN OF EXP
	CLA EXP	
	SSM	
	STO EXP	
	TRA G	
Z	CLA XLOC	X(ADDRESS) = VALUE X 10**EXP
	SUB ADDRESS	
	STA Z1	
	CLA DEC10	
	LDQ EXP	
	CALL EXP13	
	XCA	
	FMP VALUE	
Z1	STO H	VALUE = 0
AA	STZ VALUE	
	TRA F1	
BB	CLA POINT	TEST POINT
	INZ CC	
	LDQ EXP	EXP = 10 X EXP + N
	FMP DEC10	
	SSP	
	FAD NUMB	
	LDQ EXP	
	LLS 0	
	STO EXP	
	TRA B	
CC	LXA POINT,4	EXP = EXP + N/(10**POINT)
	CLA NUMB	
	FDP DEC10	
	XCA	
	TX -2,4,1	
	LDQ EXP	
	LLS 0	

	PAU EXP	
	STO EXP	
DD	CLA POINT	POINT = POINT + 1
	ADD H1	
	STO POINT	
	TRA B	
EE	CLA ALLOC	X(ADDRESS) = VALUE * 1000EXP
	SUB ADDRESS	
	STA 111	
	CLA DEC10	
	LDW EXP	
	CALL EXP13	
	XCA	
	FMP VALUE	
EE1	STO **	
	FXD 0.0	VALUE = 0
	TXH **2.4.30	+ SIGN
	SSM	SET SIGN OF VALUE
	STO VALUE	
FF	STZ EXP	EXP = 0
	AXT 2.2	FIELD = 5
	SXA FIELD.2	
	CAL ADDRESS	ADDRESS = ADDRESS + 1
	ADD H1	
	SEW ADDRESS	
GG	STZ POINT	POINT = 0
	TRA B	
HH	LXA FIELD.1	
	TXL 11.1.1	FIELD=1, EXIT
	TXL BAD.1.4	
	TXL A.1.5	FIELD=5, READ ANOTHER CARD
	TXH 11.1.6	
	CLA ALLOC	FIELD=6, X(ADDRESS) = VALUE
	SUB ADDRESS	
	STA **2	
	CLA VALUE	
	STO **	
	TRA A	
II	TXH BAD.1.7	
	CLA XLOC	FIELD=7,
	SUB ADDRESS	X(ADDRESS) = VALUE * 1000EXP
	STA 111	
	CLA DEC10	
	LDW EXP	
	CALL EXP13	
	XCA	
	FMP VALUE	
III	STO **	
	TRA A	
BAD	TSX HPRINT.4	
	PZE PRINT.0.15	
	AXT 2.1	
112	SXD **.1	
X1	AXT **.1	

X2	AXI	00.2	
X4	AXI	00.4	
EXIT	TRA	00.4	
MASK	OCT	777777700000	
PRINT	BCD	3	BAD DATA CARD...
CARD	BSS	12	
ADDRES	HTR	00	
VALUE	HTR	00	
EXP	HTR	00	
POINT	HTR	00	
FIELD	HTR	00	
COLUMN	HTR	00	
TABLE	OCT	60	BLANK
	OCT	0	0
	OCT	1	1
	OCT	2	2
	OCT	3	3
	OCT	4	4
	OCT	5	5
	OCT	6	6
	OCT	7	7
	OCT	10	8
	OCT	11	9
	OCT	20	+ SIGN
	OCT	40	- SIGN
	OCT	14	DASH
	OCT	71	Z
	OCT	70	Y
	OCT	67	X
	OCT	66	W
	OCT	65	V
	OCT	64	U
	OCT	63	T
	OCT	62	S
	OCT	51	R
	OCT	50	Q
	OCT	47	P
	OCT	46	O
	OCT	45	N
	OCT	44	M
	OCT	43	L
	OCT	42	K
	OCT	41	J
	OCT	31	I
	OCT	30	H
	OCT	27	G
	OCT	26	F
	OCT	25	E
	OCT	24	D
	OCT	23	C
	OCT	22	B
	OCT	21	A
	OCT	33	PERIOD
	OCT	73	COMMA

CHARAC HTR **
DIMENS HTR **
ADDER HTR **
H10 HTR 10
DEC10 DEC 10.0
H1 HTR 1
PROD HTR **
AMASK OCT 77777
FLOAT OCT 293000000000 .
NUMB HTR **
XLOC HTR **
CORE OCT 100001 ,
JJ SYN X1
END

OEG COMPUTER DATA SUBMITTAL FORM

Submitted by: _____ **Date:** _____

Program No. _____ Est. Time _____ Classification _____

Special Instructions: _____

[illegible]

NOTES:

1. A value of zero must be entered as 0, not left blank.
2. Decimal pts. may be omitted if understood to follow the rightmost digit.
3. The value 3×10^{-5} may be entered as .00003 or 3-5, not as 3×10^{-5} .
4. The factor portion of a value may not contain more than 8 digits.
5. The exponent portion of a value must lie within the range ± 39 .
6. Exponents may be omitted if zero. If not, they must be signed.
7. Blank cards should be indicated by: b .

**E-15
(REVERSE BLANK)**

None

Security Classification

DOCUMENT CONTROL DATA - R&D		
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1. ORIGINATING ACTIVITY (Corporate author) Operations Evaluation Group, Center for Naval Analyses of the Franklin Institute		2a. REPORT SECURITY CLASSIFICATION None
		2b. GROUP None
3. REPORT TITLE Complex Target Coverage OEG Computer Program 13-63P		
4. DESCRIPTIVE NOTES (Type of report and inclusive dates) Revised version (26 March 1965) of earlier publication.		
5. AUTHOR(S) (Last name, first name, initial) Smith, R.L., Westlund, G.A., DePoy, P.E., Ridings, R.V., and Denenberg, S.A.		
6. REPORT DATE 26 March 1965	7a. TOTAL NO OF PAGES 50	7b. NO OF REFS 2
8a. CONTRACT OR GRANT NO. NONR 3732 (00)		8b. ORIGINATOR'S REPORT NUMBER(S) OEG Research Contribution No. 68
a. PROJECT NO. -----		9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report) -----
c. -----		
d. -----		
10. AVAILABILITY/LIMITATION NOTICES Qualified requestors may obtain from DDC. Not cleared for public release.		
11. SUPPLEMENTARY NOTES Supersedes OEG Interim Research Memorandum No. 45		12. SPONSORING MILITARY ACTIVITY Office of Naval Research Navy Department Washington 25, D.C.
13. ABSTRACT <p>This research contribution presents a usage manual for an IBM 7090 computer program. The program employs a Monte Carlo simulation to determine the probability of destroying individual point targets within a target complex with one or more groups of weapons. It is assumed that the groups are delivered with a bivariate normal aiming error and that the individual weapons are distributed with an independent bivariate normal ballistic dispersion. The program is designed for conditional damage data for fragmentation generated by an IBM 7090 program furnished by the U.S. Naval Ordnance Test Station (NOTS), China Lake. A flow chart, a listing of the FORTRAN program and a sample problem are included.</p>		

DD FORM 1473
1 JAN 64

None

Security Classification

None
Security Classification

14	KEY WORDS	LINK A		LINK B		LINK C	
		ROLE	WT	ROLE	WT	ROLE	WT
	Probability of target destruction Destruction of point targets in target complex Monte Carlo simulation IBM 7090 computer program FORTRAN						

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